Depositional conditions in the southern Cis-Urals basin during Late Permian (biostratigraphic, lithofacies and petromagnetic data)

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ABSTRACT
This paper contains the results of the analysis of the Late Permian depositional environments in the southern Cis-Urals. The work is based on the data of several terms of reference sections. Thicknesses, facies and organic remains contens of the sediments were studied showing the regional stratigraphic boundaries caused by events of geologic and geographic history of the region. The main events of the geologic history were connected with the developmental pecularity of three contacted tectonic structures, *i.e.* the Ural Mountains, the marginal part of the Russian platform and the Peri-Caspian Depression.

KEY WORDS
Upper Permian, Cis-Urals, Russian Platform, Peri-Caspian Depression, biostratigraphy, petromagnetism, paleogeography.

RÉSUMÉ
Les résultats de l'analyse des paléoenvironnements de dépôts dans le sud du Cis-Oural au Permien supérieur sont présentés ici. Ce travail est fondé sur les données de plusieurs dizaines de coupes de références. Les épaisseurs, faciès et contenu paléontologique mettent en évidence des limites correspondant à des événements de l'histoire géologique et géographique de la région. Les principaux événements sont en connexion avec le développement des trois grandes unités tectoniques encadrant la région : l'Oural, la bordure de la Plate-forme Russe et la Dépression Peri-Caspienne.

MOTS CLÉS
Permien supérieur, Cis-Oural, Plate-forme Russe, Dépression Peri-Caspienne, biostratigraphie, pétromagnétisme, paléogéographie.

INTRODUCTION

The South Cis-Ural Region, embracing several northern districts of Orenburg region and a part of south-western Bashkiria, occupies an area of about forty thousand square kilometers within 51°53'30"N and 55-57°E. This rectangular territorial detachment is limited by the Ural Mountains to the east and the Salmysh River valley to the west, its northern boundary is conventionally drawn along the Salavat latitude, and the southern one along the Sol-Iletsk latitude.

The region is of special geological interest, since it represents a complicated tectonic junction, a meeting point of several major structures: the south-eastern fringe of the Russian Platform, the Cis-Ural Marginal Deflection, the Uralfolds area and the Peri-Caspian Depression (Fig. 1).

The morpho-tectonic structure of the region developed and took shape in the Late Permian, in the process of the Ural geosyncline closure at the final stages of the Hercynian tectonic cycle. Active orogeny in the Ural Mountains zone, inception of the Cis-Ural Marginal Deflection, epi-orogenic oscillations at the edge of the Russian Plate and an extensive transgression of the boreal Kazanian sea, have determined the succession of the Late Permian paleogeographic events not only for the South Cis-Urals but for the adjacent areas of the Tethys northern fringes as well.

The major part of the territory described is occupied by the Cis-Ural Marginal Deflection filled with the Upper Permian and Lower Triassic red-bed deposits with the underlying Kungurian sequence. The southern part of the Deflection, between the Bashkir Arch and the Peri-Caspian Depression, is known under the name of the Belskaya Depression; its eastern border is marked by the front ridge of the Ural Mountains and the western one is established by the steep sinking of the Kungurian salt-complex roof. The last phenomenon is clearly recorded by the sub-southern zone of isohypse closeness in the reference electric horizon (Mavrin 1970, 1979).

The Cis-Ural Marginal Deflection within the territory considered may be divided into the western, central and eastern zones according to the structural-facies features of the Upper Permian red-bed molasse. The boundaries of the structural-facial zones are indicated by two sub-southern belts of linear rises of the Kungurian halogenic sequence marked by salt-dome chains (Fig. 1).

RESEARCH SUBJECT

The paper deals with analyses of Late Permian

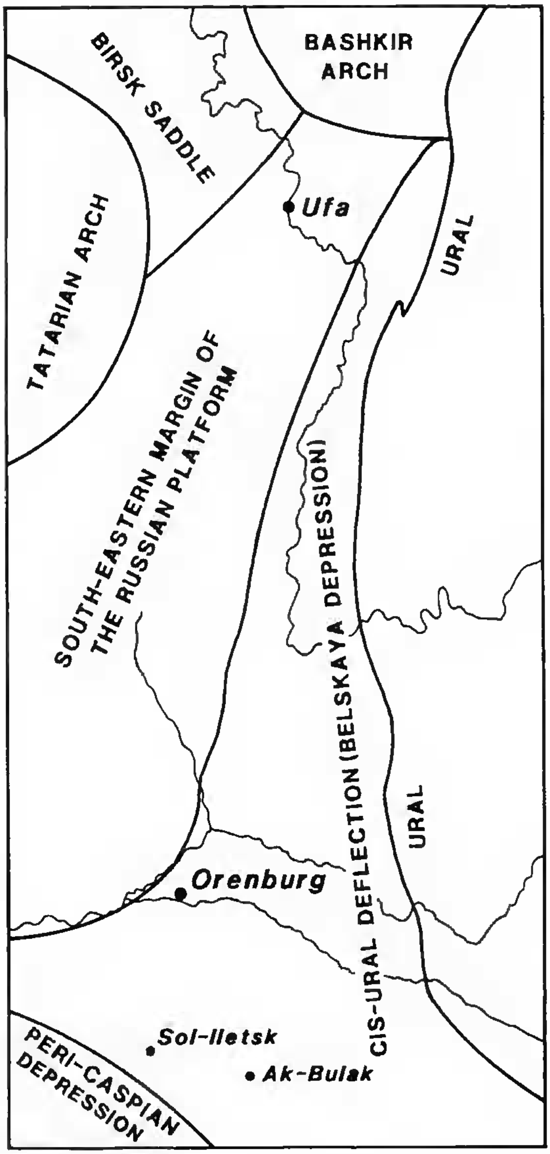


FIG. 1. — Main structural elements of the southern Cis-Ural.

depositional settings in the South Cis-Ural region. The research is based on the materials collected by the authors in the process of geological surveying and thematic paleomagnetic and biostratigraphic studies (Molostovsky & Molostovskaya 1967; Molostovskaya 1974, 1985, 1993). It summarises the original data on several tens of reference sections and wells, and the materials of Kotsehetkova (1970), Kuleva (1975, 1979), Tverdokhlebov (Kuleva & Tverdokhlebov 1974), Forsh (1955).

Beside lithofacies and paleontological data, the paleogeographic reconstructions involved the use of measurements of scalar magnetic rock characteristics: natural remnant magnetism (Jn) and magnetic susceptibility (æ). The fundamentals of magnetometric data interpretation are presented in detail elsewhere (Molostovsky 1969, 1986); in essence, the levels of rock magnetisation are controlled mainly by ferromagnetic mineral concentrations. Sedimentary sequence saturation with terrigenous magnetic material is directly related to the paleogeographic conditions of sedimentogenesis and with the geodynamic settings in the source land provinces. In the peculiar settings of the South Cis-Urals, magnetic parameters proved to be a sensitive indicator of the principal Late Permian tectonic speeding up of the folded Urals, since the Paleozoic volcanogenic sequences of the Trans-Urals provided the main magnetic-material input to the Cis-Ural Deflection (Molostovsky 1969).

SEDIMENTATION CYCLES IN THE LATE PERMIAN

Five sedimentation cycles are quite distinct in the Late Permian history of the South Cis-Urals: the Ufimian, Early Kazanian, Late Kazanian, Early and Late Tatarian ones. Each of them was caused by major tectonic and landscape-climatic changes, recorded in the lithofacies, paleontological and petromagnetic characteristics of the Upper Permian formation complex.

THE UFIMIAN SEDIMENTATION CYCLE

The first stages of the Late Permian sedimentogenesis coincided with the Kungurian saliferous basin extinction, related to tectonic movement speeding up within the folded Urals zone and with the input of significant amounts of fresh water and terrigenous materials.

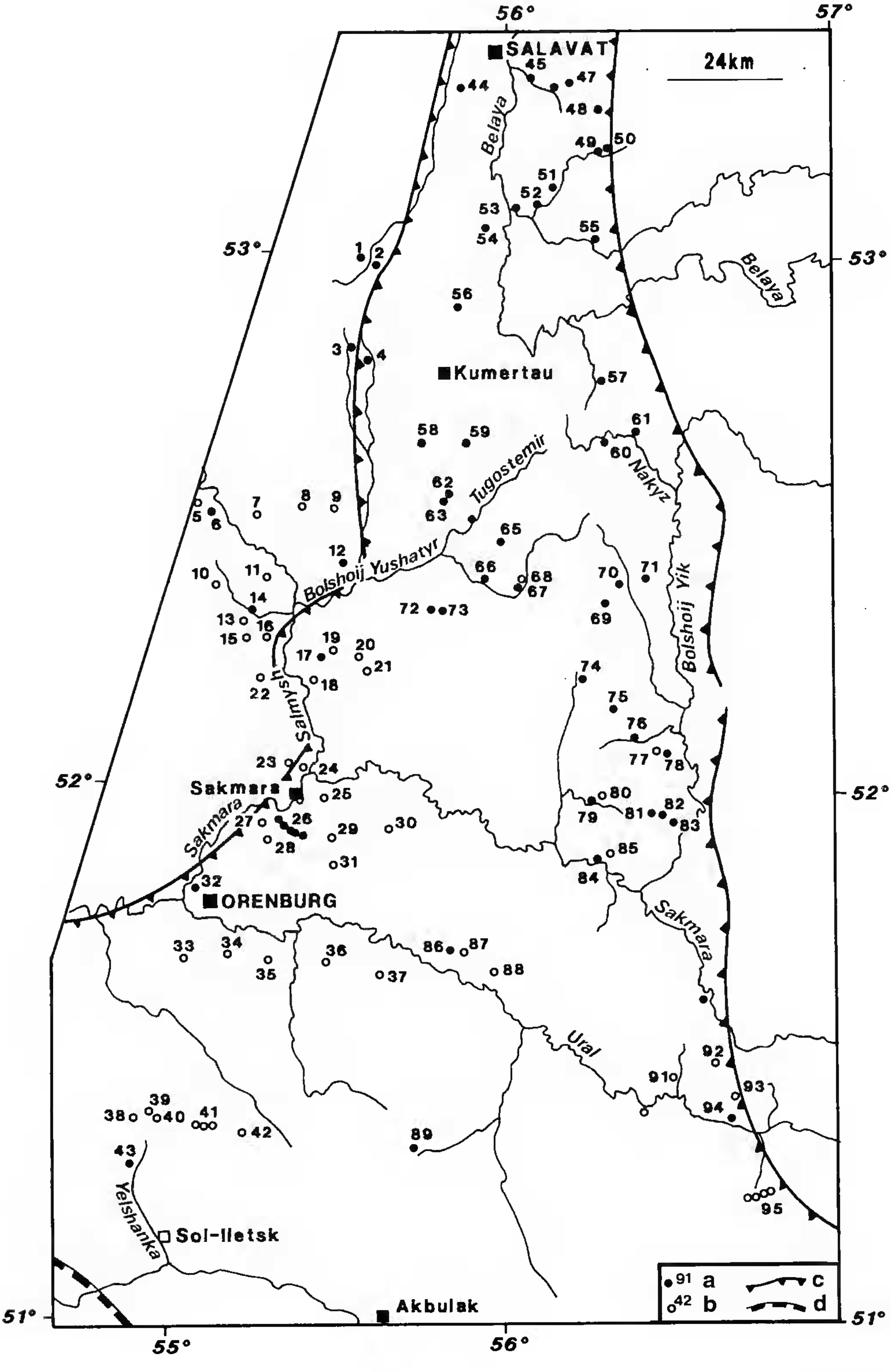
Strong magnetisation of the Ufimian deposits in the eastern zone of the marginal deflection indicates that denudation has affected the Paleozoic volcanites in the eastern zone of the folded Urals, and that the Belskaya Depression existed as a negative morphostructure as early as in the beginning of the Late Permian.

In the platform part of the South Cis-Urals, the Early Ufimian sedimentation took place under the conditions of a shallow residual basin with an unstable salt regime. In the Orenburg district, within the zone of the Salmysh rises, accumulation of red-bed siltites and sandstones started, alternating with evaporites-gypsums, dolomites, dolomitised marls and limestones.

As the post-Kungurian reservoir was gradually freshening, and the laeustrine-alluvial plain was being formed, the Orenburg Cis-Urals have become the area for terrigenous continental sedimentation which brought about a red-bed silt-sandstone sequence about 100-150 m thick. The principal structure peculiarities of the southern type Ufimian section are recorded in numerous outcrops and wells.

To the north of the region considered, within the Bashkir Cis-Urals, saliferous basin relicts were preserved in the first stages of the Ufimian sedimentation cycle. Dolomites, dolomitised limestones, gypsums and anhydrites were still accumulating intensively enough; their grey-coloured sequence is recognised as the Solikamsk horizon (Kochetkova 1970). In the second half of the Ufimian age, the paleogeographic setting was gradually adjusting and the red-bed Sheshma horizon from southern Bashkiria is identical to the corresponding deposits from the Orenburg Cis-Urals in its lithofacies features.

Aquatic biota is represented by non-marine ostracodes, bivalves and rare conchostracans. The most rich biocoenoses are associated with the upper half of the section. Among ostracodes, those of the genera *Paleodarwinula* and *Prasuchonella* are the most common, *Darwinuloides* and *Sinusuella* are less abundant. Ostracode biocoenoses are characterized by rather large den-


56°
57°
SALAVAT
24km
Belaya
53°
Belaya
Kumertau
Tugostemir
Nakyz
Bolshoij Yushatyr
Bolshoij Yik
Salmysh
Sakmara
52°
Sakmara
ORENBURG
Sakmara
Ural
Yelshanka
Sol-Iletsk
Akbulak
51°
55°
56°
a
b
c
d

sities and extents. Clayey or carbonate silts served as biotopes for them. Bivalves are represented by the species of *Palaemutela* and *Palaeanodonta* genus. Their rare localities are associated with clay interlayers.

The first plastic deformations of the hydrochemical sequence and origination of the salt-dome rises in the marginal deflection began with the Ufimian tectonic activation. An opinion exists, that the principal diapirism processes in the South Cis-Urals are associated with the Early/Middle Triassic boundary (Garyainov *et al.* 1973). Nevertheless, analyses of the Upper Permian marine facies spatial distributions show that as early as the beginning of the Kazanian age, many salt domes, as well as anticline structures of the Salmysh zone, were clearly expressed as positive forms of the ancient landscape.

THE EARLY KAZANIAN CYCLE

Since the beginning of the Kazanian boreal sea transgression, a predominantly terrigenous sedimentation regime was established in the Cis-Urals, under the shelf-zone conditions of an extensive basin with its central part in the Volga region and in the north of European Russia (Forsh 1955). The transgression proceeded in a relatively calm hydrodynamic setting with gradual change of continental and marine series. With gradual basin deepening, formation of a grey-bed sequence began, consisting of pyritized clays and siltites with subordinate sandstone interlayers and solitary thin layers of limestones.

Great abundance of thinly dispersed plant organics and a stagnant hydrodynamic regime within subaquatic depressions favoured the formation of a reducing environment with pronounced hydrogen sulphide contamination.

Bottom water geochemistry caused the impoverished biocoenoses in the lower horizons of the Kazanian stage; those are mainly represented by small-sized thin-walled brachiopods of the genus *Lingula*.

The Kazanian transgression maximum was accompanied by a general normalisation of the hydrochemical regime, first of all, in the elevated areas of the sea-bottom. It was there, in the well-aerated, clean shoal sites, that organogenic-clastic limestones started to accumulate, with diverse and rich communities of brachiopods, bryozoans, algae, corals, crinoids, foraminifers and ostracodes.

FIG. 2. — Location of the Upper Permian sections in south-east of the Russian plate and Cis-Ural Deflection. **a**, natural section; **b**, well; **c**, structural limits of Cis-Ural Deflection; **d**, limit of Peri-Caspian Depression. Others symbols of legend in figure 6. Sections numbers: **1**, Novo-Kandaurovka (the Chekushu - the Sukhalya River tributary), **2**, Korneyevka, the Sukhalya River; **3**, Yumaty, the Sukhalya River; **4**, Yalchikayevo, the Shaltanka River; **5**, well 104, Byelozyorka, the Salmysh River; **6** Karmalka, the Salmysh river; **7**, well 124, Petrovka; **8**, well 122, Verkhni Gumbet; **9**, well 123, Voskresenskoye; **10**, well 13^{sh}, the Shestimir River; **11**, well 12^{sh}, the Shestimir River; **12**, Nizhni Babalar; **13**, well 388, Yangiz, **14**, the Shestimir River; **15**, well 152^{k}, Maryevka, the Salmysh River; **16**, well 157^{k}, Maryevka; **17**, Brody Spring; **18**, well 3, Brody; **19**, well 43^{k}, Tiryak-Lizyak; **20**, well 48^{k}, State farm Oktyabrskij; **21**, well 55, Budyonnovskij; **22**, well 52^{k}, Anatolyevka, the Salmysh River; **23**, well 2^{k}, Sakmara; **24**, well 1^{k}, Sakmara; **25**, well 31^{k}, Grebeni; **26**, Krasny Gully, Grebeni; **27**, 5^{k}, Grebeni; **28**, well 7^{k}, Grebeni; **29**, well 39^{k}, Grebeni; **30**, well 6^{k}, Chebenki; **31**, well 30, Nezhenka; **32**, Orenburg. **33**, well 70^{r}, Bolshoj Sulak; **34**, well 94^{k}, Bolshoj Sulak. **35**, well 80, Dzhuan-Tyubinskaya; **36**, well 79^{k}, Dzhuan-Tyubinskaya; **37**, well 98^{k}, Karavanny; **38**, well 59^{i}, Boyevaya Mt.; **39**, well 60^{r}, Boyevaya Mt.; **40**, well 53^{i}, Boyevaya Mt., **41**, wells 81^{k}-87^{k}, Krasnoyarka; **42**, well 73^{k}, Kamennaya; **43**, Yelshanka; **44**, Korneyevka, the Yarykly River; **45**, Yeldashevo, the Yurgashka River; **46**, Skvorchikha, the Yergabusha River; **47**, Osipovka, the Budenya. **48**, Karatalka, the Teiryuk River; **49**, Rodnikovsk, the Teiryuk River; **50**, Verkhotor, the Tor River; **51**, Voskresenskoye, the Tor River; **52**, Vesyoly, the Nugush River; **53**, Krasnogorka, the Nugush River; **54**, Lipovka; **55**, Alexandrovka, the Nugush River; **56**, Yumaguzino, the Meleuz; **57**, Kadyrovo, the Menyu River; **58**, Malakanovo; **59**, Sergeyevskij, the Chukur, Bulyak River, the Bolshoj Yushatur tributary; **60**, Chernigovskij; **61**, Bekechevo, the Nakuz River; **62**, Savelyevskij; **63**, Sankinskij; **64**, Raznomoika, the Tugostemir River; **65**, Slavyanka; **66**, Allaberdino; **67**, Davletkulovo, the Yaman-Yushatyr River; **68**, well 28 and well 43, Davletkulovo; **69**, the Tashla River; **70**, Alexandrovka, the Kuplya River; **71**, Urman-Tashla; **72**, Kasteninskij, the Bolshoi Yushatur River basin; **73**, Maslovskij, the Bolshoi Yushatur River basin; **74**, Smirnovka; **75**, Alebastrovaya; **76**, Cherepanovka, the Burunchar River; **77**, well 41, Staroselka, the Bolshoi Ik River; **78**, Staroselka; **79**, Dmitriyevskij; **80**, well 4^{r} and 5^{r}, Dmitriyevskij; **81**, Stary Kazlair, the Chena River; **82**, Novosyolki, the Chena River; **83**, Kholmogory, the Bolshoi Ik River; **84**, Novokulchumovo, the Sakmara River; **85**, well 121, Novokulchumovo; **86**, Vyazovka, the Ural River; **87**, well 102, Vyazovka; **88**, well 19^{k}, Ostrovnoye, the Ural River; **89**, Blumental Gully, the Burtya river, T_1; **90**, Zholtoye, the Sakmara River; **91**, Giryal, the Ural River; **92**, well 73, Activny; **93**, well 44, Verkhneozernoye, the Ural River, **94**, Verkhneozernoye, **95**, wells' profile 5-22, the Burtya River; **96**, **97**, **98**, Tyater River; **99**, **100**, the Net River; **101**, Zildyarovo (Forsh 1955); **102**, Artyukhovka (Forsh 1955), **103-109**, the northern-profile wells of the "Buguruslanneft" trust (Forsh 1955); **110**, Fyodorovka (Forsh 1955); **111**, Kardaly (Forsh 1955); **112**, Shaktyr (Forsh 1955).

Brachiopods are represented by the genera *Cleiothyridina*, *Stepanoviella*, *Cancrinella*, *Licharewia*, *Dielasma*, *Beecheria*, *Aulosteges*.
Foraminifers, by *Hyperammina*, *Glomospira*, *Ammodiscus*, *Cornuspira*, *Calcitornella*, *Nodosaria*, *Pseudonodosaria*, *Frondicularia*, *Geinitzina*, etc.
Ostracodes, by *Healdia*, *Cavellina*, *Bairdia*, *Actuaria*, *Acratia*, *Amphissites*, *Moorea*, *Pseudoparaparchites*, *Monoceratina*, *Fascianella*, etc.

Calcareous silts and limestones were deposited in local depressions during that period.
The clayey-siltites and limestone members combined constitute the transgressive part of the marine series that maintains its structure within the whole of the South Cis-Urals region. The peculiarities of the spatial distribution of the transgressive rhythm facies are presented in the scheme (Fig. 3).
In the north-western part of the region, in the upper reaches of the Salmysh River and in the basins of the Tyater and Ashkadar Rivers, the Lower Kazanian sequence is represented by a complicated inter layering of clays, siltites, sandstones and limestones.
Siltites and clays dominate in the section to the south. The limestone member is present everywhere, but its thickness changes rapidly from 1-2 to 7-12 m.
The transgressive series sediments are up to 90-100 m thick in the north-western part of the region; the thickness decreases to 50-60 m regularly to the south and to the east.
The Kazanian sea regression was accompanied by rapid shallowing of the eastern shelf, where a member of grey-coloured cross-bedded sandstones and sandy siltites was formed, completing the section of the Kazanian marine deposits.
In the western part of the deflection, marine sedimentation proceeded under the same conditions as in the adjacent regions of the platform; this is shown by the uniform facies sequence within stratigraphic sections.
The extreme point where marine formations are established within the deflection is located on the eastern flank of the Dzhuvan-Tyubinskoye rise (E-SE of Orenburg), close to the western salt-dome range (Fig. 3, No. 36). This rise-system was probably controling the position of the Kazanian sea shore-line during its maximum transgression.
A terrigenous sedimentation regime under the conditions of a brackish-water basin was established in the central part of the deflection at the beginning of the Kazanian age. Marine facies analogues are represented by a sequence of dark-grey siltites, clays and fine-grained sandstones, saturated with dispersed plant detritus (Fig. 3, No. 87, 88).
Non-marine ostracodes, *Paleodarwinula* and *Darwinuloides*, occur within them, as well as the Belebej complex bivalves (*Palaeomutela* and *Palaeanodonta)* and a spore-pollen complex, analogous to the Early Kazanian marine-bed palynocomplex in its composition.
The eastern part of the deflection at the beginning of the Kazanian age has become an active homogenic sedimentation zone; the products of this sedimentation are traced within a narrow (10-12 km) piedmont band over more than 100 km, from the Tashla river in the south to the Tor and Nugush rivers close to the northern extremes of the Belskaya Depression (Fig. 3, No. 51, 61). Dolomites, dolomitised limestones and marls, and, to a lesser extent, grey-coloured clays and siltites were accumulating there. Siltitic-clayey sediment became dominant in the section while the basin was gradually freshening and the terrigenous drift became more intensive.
Ostracode and mollusc biocoenoses are concentrated within the upper, less mineralised horizons of the lagoonal sequence. They are represented by brackish-water species of *Darwinuloides* and *Paleodarwinula*, common for the whole of the Kazanian stage; that is why correlation of these facies to marine deposits from the western regions is established from palynologic data (Kuleva 1975). The whole of the 150 m thick lagoonal sequence, irrespective of its rock-compositions, is distinguished for extremely low magnetisation ($Jn = 0.5\text{-}1.5 \times 10^{-5}$ A/m, $æ = 214 \times 10^{-5}$ SI units). The lack of magnetic material in the sediments shows that the lagoon was completely isolated by the surrounding salt-dome rises. The terrigenous drift was later on accomplished at the expense of baring of the Lower Permian and Carboniferous weakly magnetised terrigenous and carbonate sequences

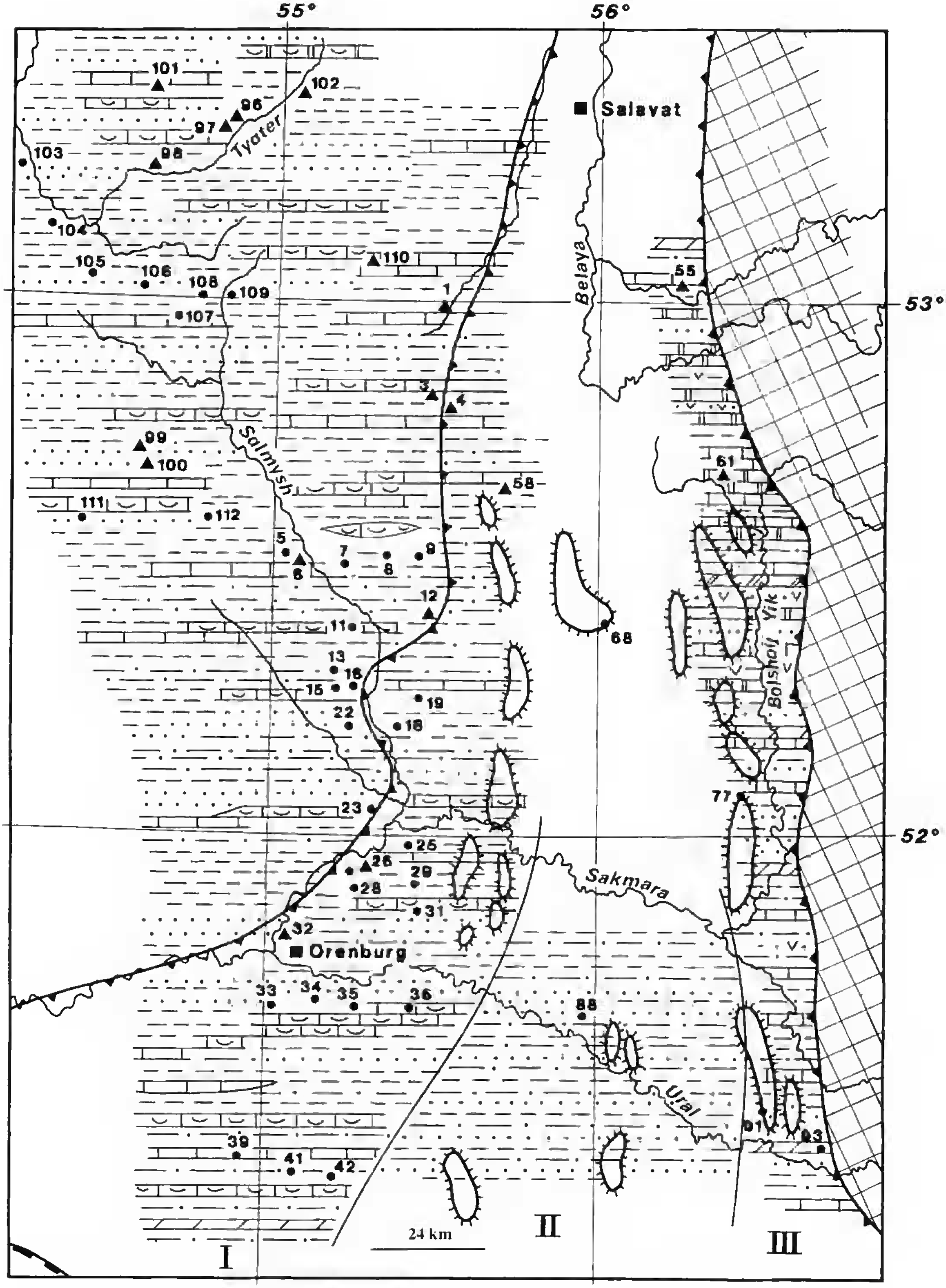


FIG. 3. — Lithofacies scheme of southern Cis-Ural - early Kazanian (legend in figure 6).

from the western slopes of the Urals.
No lagoonal facies have been reliably revealed in the southern part of the eastern zone, and the Lower Kazanian substage was thought to comprise the grey-coloured sequence of alluvial-deltaic sandstones and siltites with rare clay and marl interlayers, containing the remains of freshwater bivalves and land vertebrates (Kuleva & Tverdokhlebov 1974).

The late Kazanian sedimentation cycle

The middle of the Kazanian age represented a turning point in the South Cis-Urals geologic history. A continental sedimentation regime has finally established itself in the region as the result of the Urals tectonic activation and the Boreal Sea regression towards the centre of the Russian Plate.

The Cis-Ural Deflection and the adjacent regions of the Platform have changed into an extensive accumulative plain with a complicated combination of basin, lagoonal, lacustrine and alluvial-proluvial facies; both southern and latitudinal zonings were evident in their spatial distributions (Fig. 4). In the south, within the Ural and Salmysh Rivers Basins, basinal terrigenous sedimentation has established itself, and a monotonous interlaid sequence was accumulating of siltites, clays and fine-grained sands with single interlayers of marls and obliquely-laminated polymictic sandstones of deltaic type. In the western part of the deflection and in the platform, mostly red-bed sediments were developing.

In the south of the central zone of the deflection, a sequence was formed of interlayering red-beds and grey rocks.

The principal portion of the deflection central zone was occupied by a lacustrine-alluvial plain, accumulating a complex of red-coloured aleuropelitic deposits with subordinate interlayers of fine-grained sands and clayey limestones. A limited amount of sandy-conglomerate facies of channel alluvium is represented in the section.

The northern regions, embracing the Nugush, Belaya and Dyoma basins, were occupied by a major interior reservoir with increased mineralisation; it was limited with a number of salt domes from the south. An interlayering sequence of siltites, clays, limestones and marls has accumulated within it. Sulphates were precipitating at some sites (Kochetkova 1970).

A narrow piedmont band along the eastern border of the deflection comprised an alluvial-proluvial plain, where the principal part of the sandy-pebble material carried from the mountain Urals was deposited (Kuleva & Tverdokhlebov 1974).

The beginning of the Late Kazanian sedimentation cycle is clearly recorded in the section from the central and eastern zones of the deflection by sharp increases of rock scalar magnetic characteristics. At this boundary, the Jn and æ values increase up to 0.1-0.2 A/m and 300-500 × 10^{-5} SI units, respectively. The very character of the section petromagnetic in homogeneity testifies to a volley ejection of great amounts of terrigenous material from the Urals eastern slopes (Fig. 7).

Diverse sedimentation settings in the Cis-Urals have affected the structure of the Late Kazanian aquatic biota, which is distinguished for its species diversity, being relatively limited in the number of genera. Ostracodes of *Prasuchonell*a genus dominated in the aleuro-pelitic grounds in the zones of mobile hydro-dynamics and sulphate mineralisation of waters. Calcareous and calcareo-dolomitic grounds served as an ecological niche for srenofacial *Darwinuloides*. The clayey-calcareous lithofacies were occupied by *Paleodarwinula* and *Prasuchonella*. *Paleodarwinula* proved to be the only ones to adapt themselves to the non-carbonate silty grounds.

Widely occurring bivalves are represented by the brackish-water species of *Palaeomutela* and *Palaeonodonta*, which possessed thin-walled shells and preferred the silty sediments of hydtodynamically calm zones (Kuleva 1975, 1979).

Beside ostracodes and bivalves, few conchostracans and fish were present in the aquatic biotopes. Swamp coastal plains served as habitats for terrestrial plants and tetrapods.

The early Tatarian sedimentation cycle

The early Tatarian paleogeographic setting was determined by tectonic activity in the whole of the South Cis-Urals.

In the western part of the region, the deposits, assigned to the lowermost of the Tatarian, were

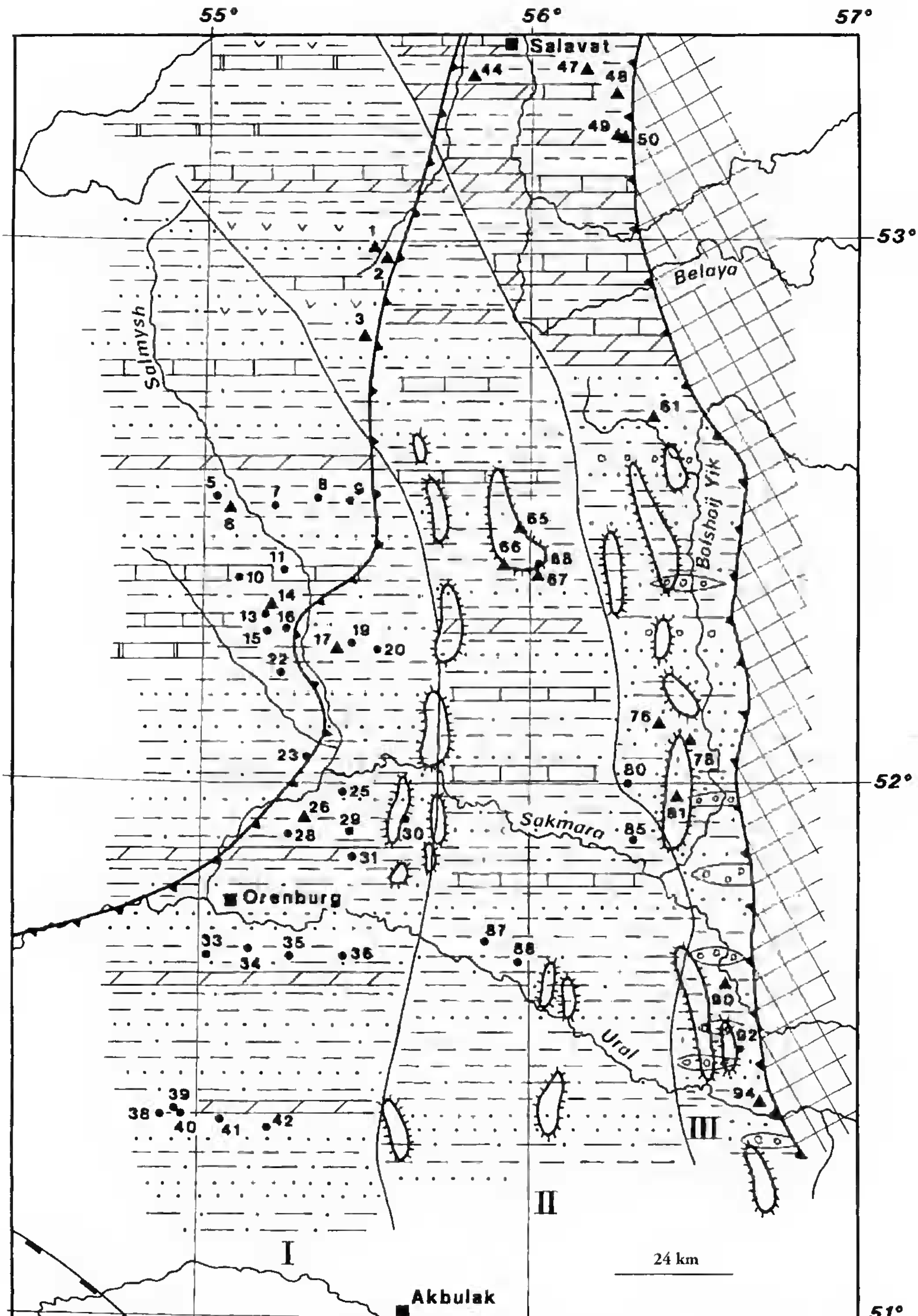


FIG. 4. — Lithofacies scheme of southern Cis-Ural - late Kazanian (legend in figure 6).

being formed in the inherited late Kazanian reservoirs with increased mineralisation. Gypsinates and stones were depositing there (Fig. 4). High sulphatisation of the reservoirs was adversely affecting the organic life development. The clayey-aleuritic grounds there were inhabited only by ostracodes of *Prasuchonella* genus, sometimes associated with rare depressed *Paleodarwinula*. Carbonate silts are associated with the localities of *Darwinuloides tscherdinzevi* Kashevarova, a typical dweller of highly mineralised carbonate reservoirs with increased magnesiality (Molostovskaya 1974).

The principal cycle of the early Tatarian sedimentation began with vast alluvial plain development; the plain is traced by a characteristic facies set in the form of a southern band to the south from the Bashkir Cis-Urals, right to the town of Sol-Iletsk. The alluvial sequence is composed mostly of cross-laminated channel sandstones and pebbles of local rocks. Less common are red-coloured aleuro-pelites of the flood plain and dead-channel facies.

In the second half of the early Tatarian cycle, the alluvial sedimentation was changed in the basinal one; its products appear in the upper horizons of the section over the sequence of alluvial sands, in the form of a member of siltite-clayey beds (Fig. 5, No. 31, 36, 42).

Eastwards, the lower Tatarian alluvial plain turned into the lacustrine-alluvial one, occupying the greater part of the central and eastern zones of the marginal deflection. A monotonous sequence of red aleuro-pelitic silts was deposited within it, with interlayers of alluvial sands and conglomerates.

Along the northern fringes of the lacustrine plain, in the basins of the Nugush, Tor and Belaya Rivers, an alluvial-deltaic regime was established during the initial stages of the Early Tatarian sedimentation; this resulted in a thick (300-400 m) sequence of cross laminated sands, gravelstones and conglomerates. Later on, a reservoir with increased water-mineralisation was formed in this territory; pelitic and carbonate silts were precipitating there (Kochetkova 1970).

In the eastern flank of the marginal deflection, the regime of alluvial-deltaic and proluvial sedimentation dominated (Fig. 5, No. 45, 46, 50, 51, 52). Within a narrow piedmont band there, a major portion of coarse clastic material was deposited; judging from its composition, this was carried from the central and western parts of the mountain Urals. According to Kuleva & Tverdodokhlebo (1974), quartz, flints, quartzites, Carboniferous and lower Permian limestones dominated in the lower Tatarian pebble stones. A significant part of the piedmont molasse consists of the proluvial material with its typical "rubbish" horizons, comprising unsorted sands, pebble stones and aleuto-pelitic sediments.

Among the organisms, inhabiting the early Tatarian reservoirs, bivalves and ostracodes are the most abundant ones. Aleuto-pelitic sediments of the flood plain type are associated with the localities of bivalves of the Kama and Chepetsk complexes, consisting of the *Palaeomutela*, *Anthraconaia* and *Palaeanodonta* genera representatives. Ostracode *Paleodarwinula* and *Paleodarwinula-Prasuchonella* communities are also associated to the same facies.

The sedimentation setting of an alluvial plain is chiefly characterised by numerous accumulations of thick-walled shells of the Doskinsky complex. The typical species of this complex, *Antraconaia verneuili* Amalizky, is a typical inhabitant of the channel facies (Kuleva 1975).

Paleodarwinula are the most common of ostracodes there.

Highly mineralised carbonate reservoirs provided rather favourable conditions for biota development. In the clayey-carbonate rocks there, alga fragments, fish scales, bivalve and ostracode shells occur. Ostracodes are most abundant. They are represented by diverse communities: *Darwinuloides*, *Darwinuloides-Paleodarwinula*, *Paleodarwinula*, *Paleodarwinula-Prasuchonella* and *Prasuchonella*.

The specific features of the changing paleogeographic setting are clearly recorded by scalar petromagnetic characteristics. In the reference sections from the central and eastern zones of the Cis-Urals Deflection, the beginning of the Early Tatarian sedimentation is marked by a sharp 4-5 fold decrease in rock magnetisation of red-bed molasse: to modal æ values 25-30 × 10^{-5} SI units with rare "bursts" up to 70-90 × 10^{-5} SI units (Molostovsky 1969).

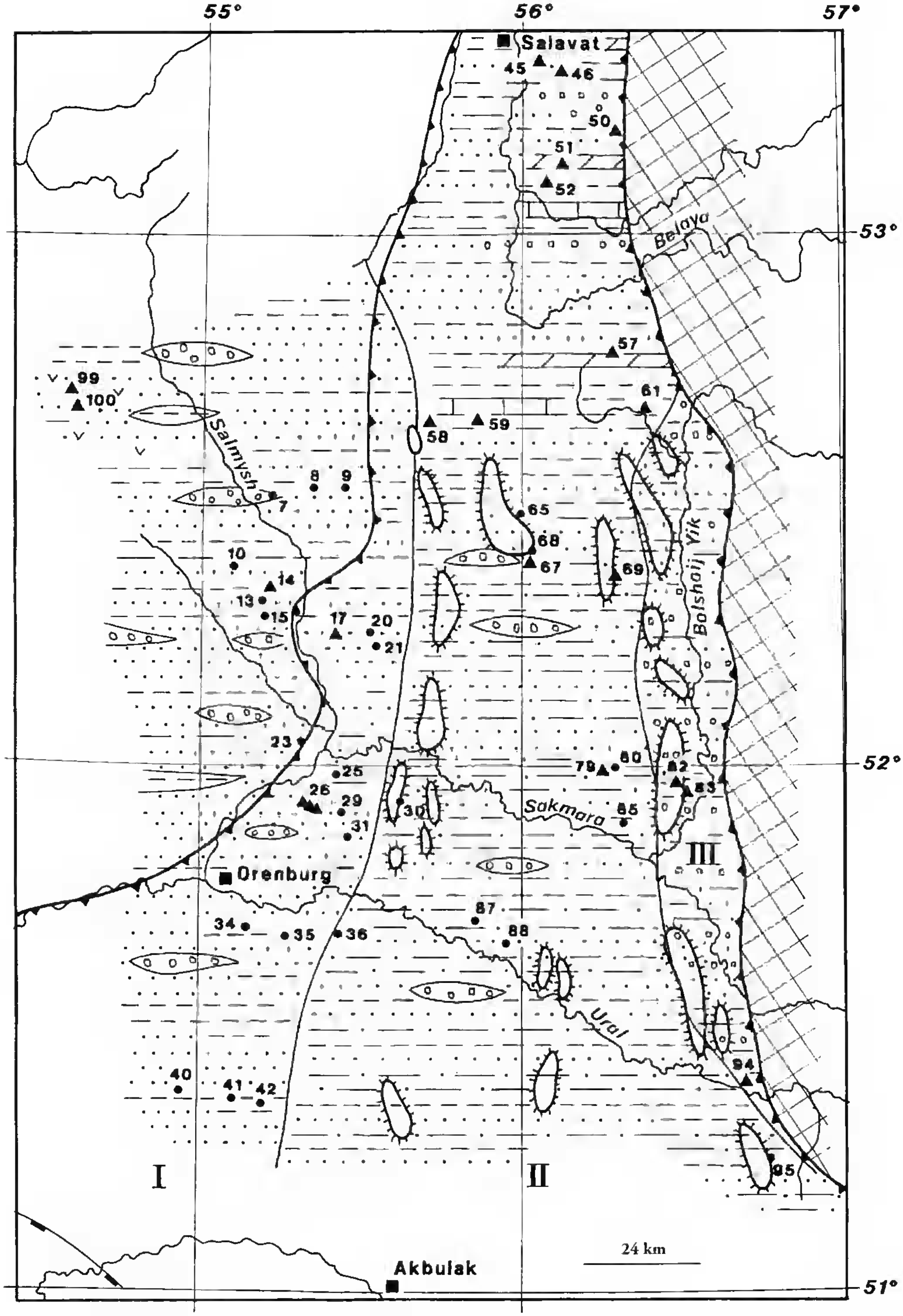


FIG. 5. — Lithofacies scheme of southern Cis-Ural - early Tatarian (legend in figure 6).

In the western part of the deflection and in the adjacent regions of the Russian Plate, the changes in the facial settings almost didn't affect magnetisation of the sediments. The basin deposits of the Kazanian age and the cross-laminated sandstones of the lower Tatarian alluvial plain are distinguished for extremely uniform decreased magnetisation with the modal Jn values of 6-9 × 10^{-3} A/m and those of æ = 12-20 × 10^{7} SI units (Fig. 7).

The peculiarities of petromagnetic section structures show that in the period of the early Tatarian sedimentation, the whole of the South Cis-Ural territory was to a significant extent isolated from the Trans-Ural source provinces. The central and eastern zones of the deflection were being filled with the terrigenous material from the sedimentary and metamorphic sequences of the western slopes of the Urals. The source lands to the western alluvial plain were probably situated in the north, in the regions of the Tatar and Bashkir Archbends, where the weakly magnetised horizons of the sedimentary cover were exposed to wash-out. Local source centres might originate within the arch portions of the local rises.

THE LATE TATARIAN SEDIMENTATION CYCLE

The late Tatarian sedimentation was preceded by the Urals ascending motions. This rising has probably involved the Salmysh Bar zone, characterized by the absence of the upper Tatarian deposits. Stable accumulation was preserved only within the deflection enclosing the marginal zone of a large epicontinental basin territorially connected with the Peri-Caspian Depression. The non uniform hydrochemical settings in the reservoir have predetermined the southern zoning in its facies spatial distribution.

Its western part, the most spread one, has become a site for terrigenous sedimentation which resulted in a homogenous sequence of interlayering red clays, siltites and fine-grained sandstones. The band of terrigenous accumulations was traced along more than 150 km from the north to the south (from Bashkiria to the town of Sol-Iletsk), but its real extent hasn't been established. This facial zone is limited by a southern band of the Kungurian rises and the Cis-Ural Deflection border to the east and to the west (Fig. 6: I).

The red-bed sequence acquires a somewhat more variegated, poly-component composition to the east, within the central zone of the deflection. Siltites and clays constitute the sections principle components there. The amount of arenaceous sediments insignificantly reduced, thin gravelite and pebble stone lenses appear, limestone and marl interlayers and calcareous clay members are encountered with accumulations of carbonate nodules and concretions.

Sediments carbonate contents increase regularly from the north to the south, and marls and limestones become important components of the sections from the basins of the Tor, Nugush and Belaya Rivers (Fig. 6: II).

The conditions of the upper Tatarian sequence formation within the central part of the deflection are analysed in detail by Botvinkina and Tverdokhlebov. Botvinkina (1962) reconstructs the hydrodynamic settings of the large marine-type basin. In Kuleva & Tverdokhlebov schemes (1974), this territory is assigned to a lacustrine-swamp plain with the accumulation level close to zero.

Significant deposit thicknesses (> 500 m), fossil-remains compositions, numerous intra-formational gaps testify to dynamic hydrogeologic regime of sedimentation against the background of intensive basin-floor deflection. This data more likely conforms to the hypothesis of a large reservoir penetrating into the low land as narrow intrusive tongues, and reaching distant northern areas, right to the periclinal closure of the Belaya depression.

In the eastern piedmont flank of the marginal deflection, similar to the early Tatarian time, a narrow alluvial-proluvial plain was situated, cut by permanent and temporary water flows. Numerous fans are formed within it, consisting of sandy, boulder-pebble and gravel materials. Limestones, flints, quartzites and variously composed effusives occur among clasts (Fig. 6: III).

The upper Tatarian deposits are distinguished for diverse petromagnetic characteristics with some certain ordering in their spatial distributions.

The pellitic arenaceous sediments from the western facial zone are marked with weak uniform magnetisation and are practically identical to the lower and upper Tatarian formations in Jn and æ values.

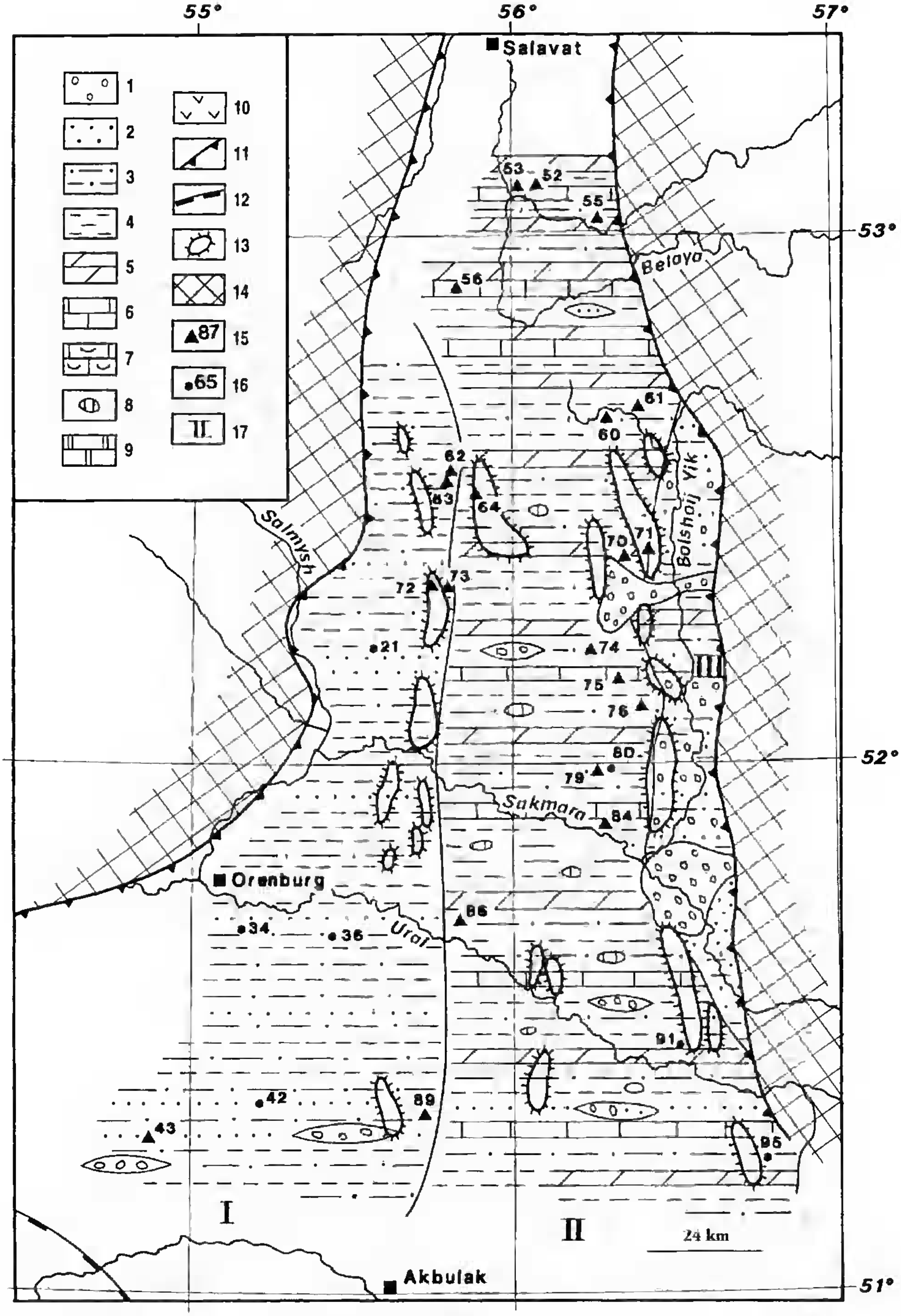


FIG. 6. — Lithofacies scheme of southern Cis-Ural - late Tatarian. Symbols for figures 2-6: **1**, conglomerates; **2**, sandstones; **3**, siltites; **4**, clays; **5**, marls; **6**, limestones; **7**, organoclastic limestones; **8**, nodular limestones; **9**, dolomites; **10**, gypsums; **11**, boundary of Cis-Ural marginal Deflection; **12**, boundary of the Peri-Caspian Depression; **13**, growing salt domes; **14**, land; **15**, outcrop; **16**, well; **17**, structural facies zones.

In the eastern and central zones of the deflection, the sequences are distinguished for extremely high non uniform magnetisations with Jn and æ values of tens and hundreds of SI units. A sharp change of weakly- and strongly-magnetisation sequences is recorded within the wells of the profile 95 (the Burlya River basin); the level of this change is practically coincident with the lower/upper Tatarian boundary (Fig. 7).

The petromagnetic data comparison makes it evident that the late Tatarian sedimentation was accompanied by the change of the source lands and that the central part of the deflection was still a kind of an accumulative bath, receiving practically all the magnetic materials carried in from the greenstone belt of the eastern Urals.

The ecological setting was favourable for the development of a rich and diverse aquatic biota. On the clayey-aleuritic grounds within the zones of relatively calm hydrodynamic settings, thin-shelled bivalves of the Vyazovsky and Oksky complexes resided, represented by *Palaeomutela*, *Palaeanodonta* and *Anthraconaia* genera. The coastal zones with moderately active hydrodynamics were occupied by the Severodvinsky complex bivalves, including *Palaeomutela*, *Palaeanodonta*, *Oligodontella* and *Opokiella* genera (Kuleva 1975).

Multiple and variously composed ostracode communities were distributed over clayey-aleuritic and carbonate grounds. The eury-facies *Suchonellina* dominated in the late Tatarian biotopes, forming independent communities there or associated with *Suchonella*, *Dvinella*, *Wjatkinella* and *Gerdalia* (Molostovskaya 1993). The steno-facies *Sinusuella*, *Permiana* and *Placidea* were usually localised within the bottom-water zones of increased carbonate mineralisation. Their rare localities are associated with marl-carbonate layers.

In the eastern zone of the deflection, an ostracode association was formed, consisting of the representatives of *Suchonellina*, *Suchonella* and numerous small endemic Cytheracopina, possessing little, elongated, sculptured shells. In their morphologic features, the latter ones are close to

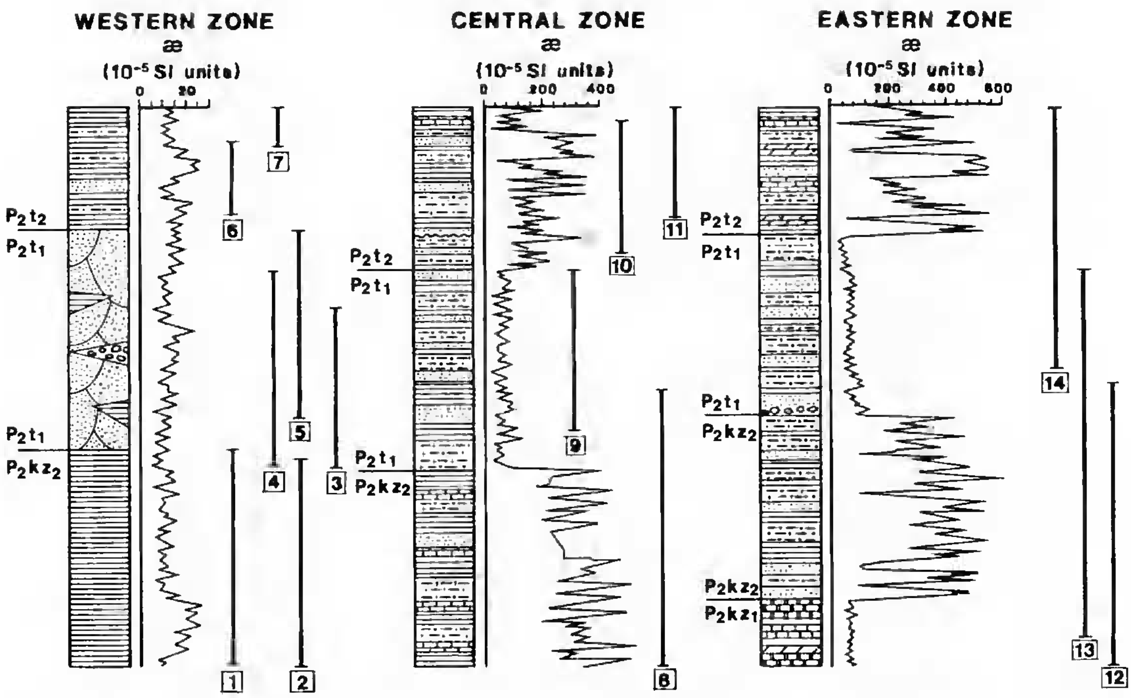


FIG. 7. — Petromagnetic curves of the Upper Permian deposits in Cis-Ural Deflection. **1**, Krasny Ravine; **2**, well 31ᵏ, Grebeni; **3**, Shestimir River; **4**, Sakmara; **5**, Brody; **6**, Yelshanka; **7**, Blumental; **8**, Davletkulova, Yaman-Yushatyr River; **9**, Sergeevsky; **10**, Vyazoka; **11**, Novokulchumova; **12**, Bekecheva, Nakyz River; **13**, Nugush River; **14**, well profile 22, Burly River.

the Triassic Cytherocopina from the Peri-Caspian Depression, but differ substantially from the upper Permian Cytherocopina from the Russian Plate. This specific complex is territorially limited within a narrow piedmont band of the marginal deflection, traced from the south to the north for over 200 km (from the Burlya River to the basins of the Tor and Nugush Rivers).

Conchostracans, gastropods, *Spirorbis* worms and algae were common, but not numerous inhabitants of the Tatarian reservoirs; their fossilised remains are also concentrated in clayey-carbonate rocks.

The marsh-ridden coastal areas of the low land served as an ecological niche for small tetrapods.

Considering various aspects of the Late Permian paleogeography of the South Cis-Urals, it is a matter of principle to realise the extent this rather peculiar local region was related with the Tethys northern fringes during its evolution. Spatially and structurally, the southern part of the Cis-Ural Marginal Deflection is continuous with the eastern part of the Peri-Caspian Depression. It is natural that correlations of stratigraphic sections and lithofacies features of the Upper Permian deposits from these regions present a special interest.

The detailed information on the structure of the Upper Permian formation from the Peri-Caspian Depression is given in the papers of Movshovich (1977), Vainblat (1969) and Zamarenov *et al.* (1969). A comparative analysis of the data on the South Cis-Urals and the Eastern Cis-Caspian reveals significant section similarities lithology, chronological succession of facies, stratigraphic boundaries character and bionomic characteristics. These similarities are especially evident for the Kazanian and Tatarian stages.

Within the Cis-Ural Deflection, as well as in the eastern Cis-Caspian region, the Kazanian stage is represented by non-marine brackish-water facies with terrigenous compositions. In the lower portion of the section, grey-coloured argillites and siltites dominate, saturated with thinly dispersed plant detritus and authigenic iron sulphides.

The upper Kazanian substage is everywhere represented by the sequences of interlaid grey- and red-coloured rocks with the latter ones clearly dominating. Vainblat (1969) and Zamarenov *et al.* (1969) suppose that the Kazanian sedimentation took place within extensive shallow-water reservoirs, experiencing hydrostatic head from the boreal basin at various stages. Lagoonal and deltaic sedimentation proceeded in individual sites.

The Tatarian stage from the eastern Cis-Caspian, as well as from the Cis-Urals, is represented by a red-coloured complicated structured terrigenous sequence, comprising variously rationed alternations of argillite and aleuro-psammite beds with rare limestone interlayers.

The total numbers of the Upper Permian sedimentation cycles in both regions are identical; it is significant, that all the stage and substage boundaries are marked with stratigraphic, and in the Cis-Caspian by angular discordances.

The peculiarity of the Upper Permian deposits from the eastern part of the Peri-Caspian Depression consists in their saturation with pebble-stone material, including flints, quartz, metamorphic shales and effusives, *i.e.* practically the whole of the typomorphic set of rocks from the central and eastern Urals.

The Ural material is present practically all over the eastern fringe of the Peri-Caspian Depression (from the Cis-Ural Deflection to the Emba River).

The lithofacies information obtained from drilling, plays a certain role in the long discussion tectonists hold on the structure of the Cis-Ural Marginal Deflection within the Peri-Caspian Depression. Goretsky (1972), Shlezinger (1974) and some other authors advocate the idea of the Cis-Ural Deflection passing into the system of periclinal deflections fringing the folded Urals from the south and south-west. Movshovich (1977), Mizinov (1974), Lapkin & Tomashunas (1966) and others provide diverse arguments in favour of the idea of an abrupt turn of the Ural folded system and the Cis-Ural Deflection to the west and their jointing the Karpinsky Ridge and the Cis-Donets marginal deflection in the northern Cis-Caspian, between Gurjev and Astrakhan.

Great abundance of pebble material in the south of the Peri-Caspian Depression represent rather substantial arguments in favour of the second conception.

The ring of the Hercynian structures during the whole of the Late Permian was acting as an effective barrier isolating the epicontinental Cis-Caspian basin from the Tethys. The Cis-Caspian geographic isolation from the region of marine sedimentation has affected the structure of the Upper Permian biota, which in its ostracode and bivalve composition was very similar to those from the Russian Plate and the Cis-Ural Marginal Deflection. In the sections from the Cis-Caspian region, ostracodes are represented by *Darwinula*, *Darwinuloides*, *Suchonella*, *Suchonellina* genera. Among bivalves, the brackish-water genera *Palaeomutela* and *Palaeonodonta* are indicated.

Lithologic-facies and paleontologic records testify to the autonomous development of the epicontinental Cis-Caspian reservoir in the Late Permian and don't provide any more or less substantial arguments in favour of its recurrent connections with the Tethys.

CONCLUSION

The mean features of the Late Permian paleogeography in the South Cis-Urals were determined by the tectonic activity of the Ural orogen, and in the beginning of the Kazanian (by an extensive boreal transgression). Each sedimentation cycle was preceded by the Urals uplifting, baring processes animation within the source lands and regional wash-outs in accumulation basins. Consequently, the boundaries between the Upper Permian stratigraphic units are of episodic character and correspond to the initial stages of sedimentation cycles.

The central and the eastern zones of the marginal deflection, during the whole of the Late Permian epoch, existed as a major depression morphostructure, accumulating the main portion of the allothigenic material arriving from the region of the folded Urals. The western part of the deflection, in its present configuration, has a lot in common with the adjacent areas of the Russian Plate in lithology and thicknesses, and constitutes a single structural-facies zone with the Plate.

One may suppose that the western border of the deflection in the end of the Permian was situated to the east of its present position and ran over the zone of the southern Kungurian elevations. Thus, some migration of the deflection axis towards the Platform is outlined, which is generally characteristic of such structures type.

Southern zoning is outlined in the lithofacies spatial distribution within the marginal deflection; a sufficient role in this deflection origination was played by the western and eastern zones of linear elevations of the Kungurian halogenic sequence. Besides, the sub-latitudinal zonality is outlined in distribution of the evaporite and terrigenous facies; this zonality persists at all the stages of the Late Permian sedimentogenesis: from the Ufimian through the late Tatarian.

The main portion of the sulphate-carbonate accumulations is concentrated in the northern part of the region, where a system of inherited lagoon-type reservoir is known to have existed for a long time. The terrigenous sedimentation in the southern regions is most logically explained by an active river discharge and, consequently, by accumulation - basins freshening. The analyses of thicknesses, facies and organic remains compositions, demonstrate that generally basin sedimenration regime prevailed in the south of Cis-Urals, with wide development of low accumulative plains characterised by alluvial-proluvial and lacustrine-swamp sedimentation.

Not withstanding peculiar paleogeographic settings, caused by the proximity of the mountain Urals, the South Cis-Urals region in its geologic development was closely related both to the marginal part of the Russian Platform and to the Peri-Caspian Depression.

The Cis-Ural Deflection reveals a lot of similarities with the eastern part of the Peri-Caspian Depression in lithology, facies set and biota composition. It used to represent just a narrow gulf of an extensive epicontinental reservoir.

An active material discharge from the Mountain Urals region constitutes a peculiar feature of the Late Permian sedimentogenesis in the eastern Cis-Caspian and South Cis-Urals. The influence of the Urals is revealed all over the eastern fringes of the Peri-Caspian Depression: from the Ural River valley in the north to the Emba River basin in the south.

The analyses of the data on the upper Permian deposits from this region show that the intracontinental basin of the Cis-Caspian in the Late

Permian was developing in an autonomous regime and didn't have any long-term connections with the Tethys area. The natural barrier between them consisted of the system of the Hercynian mountain structures of the Urals and Karpinsky Embankment, joining each other in the zone of the present-day Caspian aquatorium, in the area between the Ural and the Volga mouths. This isolation was broken up in the Olenekian age and in the Middle Triassic, when major invasions of the Tethys into the Cis-Caspian region occurred. No events of similar scale have been revealed in the Late Permian, but this problem needs special studying.

In this connection, the communities of intricately-sculptured Cytheracea seem rather interesting; they appeared in the south of the Cis-Ural Marginal Deflection in the second half of the Tatarian age. In their morphologic features they are similar to certain Cytheracea from the Middle Triassic Cis-Caspian complex, which, according to Lipatova & Starozhilova (1968), is analogous to the ostracode complex from the Middle Triassic of Germany. Very small ostracodes with smooth-valve shells also occur there; they are morphologically similar to *Paracypris*, the representatives of which are common mainly in seas. Origination centres and movement tracks of these ostracodes are still unknown. They may prove to be endemic, but one can't rule out the possibility of their being some southern migrants, to certain extent associated with the marginal part of the Tethys.

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